Structural Inspection and
O&M, Occupational and Public Safety Review
of the
Hot Springs Tunnel System,
Hot Springs National Park
Hot Springs, Arkansas

August, 1993

Prepared by:

Bureau of Reclamation
Denver Office

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1.0 Executive Summary

A structural inspection and a review of the operation and maintenance, occupational and public safety conditions of the Hot Springs Tunnel System in Hot Springs National Park and the City of Hot Springs Arkansas revealed two serious deficiencies which require immediate action.

Near the intersection of Loadstone and Arbor Streets a concrete structure covers the tunnel. It is possible for vehicles to access the top of the structure which does not appear to be adequate to support vehicular traffic. The structure also contains unprotected openings to the tunnel below. This condition is a serious deficiency with significant public safety hazard potential

Erosion of the foundation of the sidewalls of the tunnel is a serious structural problem. Planning, engineering and budget programming to solve the problem should begin immediately. The worst areas of erosion should be identified and repaired within two years.

This report contains the following recommendations:

The first recommendation concerns the unsafe condition of the vault structure. Action is required immediately (analogous to safety of dams category SOD1).

1993-T1-1. Fence the vault area near the intersection of Loadstone and Arbor streets and cover openings to the tunnel.

The recommendations below affect the safety of the tunnel and the surface area subject to flooding. Action is required within 24 months (analogous to safety of dams category SOD2).

1993-T2-2 Complete an engineering inspection of the entire tunnel system. Prepare drawings showing all pipe connections and piping systems in the tunnel. Show all exhibiting structural anomalies. Prepare a specification for repair of the undercutting of the sidewalls of the tunnel.

1993-T2-3 Analyze the need for safety racks at the entrances to the tunnels. Establish the consequences of flooding due to trash blockage of the tunnel entrances.

1993-T2-4 Install guardrail, handrail and warning signs as directed by the Hot Springs National Park safety officer.

2.0 Purpose

The purpose of this report is to describe the structural condition of the existing tunnel system. A companion report by Lex Kamstra and Patricia Hagan-Chagnon of the Bureau of Reclamation entitled "Flood Warning Enhancements for Hot Springs National Park, Arkansas" discusses the hydrology of the area and the hydraulics of the Hot Springs Tunnel System. Some comments on the operation and maintenance of the tunnel system and public safety aspects of the tunnel entrances are included in this report.

2.1 Introduction

Hot Springs National Park protects a unique natural resource and a site of significant historical interest. While the 143 °F mineral waters flow predictably to the various bath houses in Hot Springs; storm waters from the basin above frequently result in flooding and disruption of access to the hot springs. In 1883, the Hot Springs Tunnel System was constructed to solve the problem of flooding in Hot Springs. The tunnel does contain storm water from the most frequent storms; however, flooding through the National Park and in the City of Hot Springs remains a problem. The general problem of flooding in the Park and in the City involves the interests of the National Park the interests of the City and a complicated decision process to choose solutions from several structural and non-structural proposals. This report does not discuss potential solutions to the problem of flooding. Figure 2.1 shows the topography of the area, the drainage conduits and the location of historic bath house row in the constricted valley between West Mountain and Hot Springs Mountain.

2.2 Historical Perspective

In 1882 the growing popularity of the natural hot springs in Arkansas as a tourist destination resulted in contention for access to the area and a need for management of this important resource. The problem was described in 1882 as follows:

> " ... In consequence of this encroachment and the rough and obstructed character of the creek channel it is at times unable to carry away the storm waters that fall into it. It overflows its banks, to the great inconvenience of the inhabitants, and not infrequently to their pecuniary detriment."

An open flume structure constructed of imported granite masonry walls was designed to solve the flooding problem and a contract was awarded for it construction in May 1883.

Since it's inception in 1882, and continuing to this day the Hot Springs Tunnel System and the solution to flooding in Hot Springs have generated engineering controversy. In 1883, the construction under the original contract was observed by several bath house visitors and roundly criticized. Mr Joseph E. Brown decried the lack of a cover and the failure to use native stone. Mr. H. B. Maxey also wrote the secretary of the Interior to suggest a closed arch which would accomplish "...first, a broadnening of the street, which is necessary; second, a splendid sewer ample for the entire village, with a swift stream of water to keep it clean."

After extensive public discussion, the Superintendent and Engineer in charge of the Hot

Springs Creek Improvement requested a structural analysis of the proposals to revise the design. Architect J.L. Smithmeyer analyzed a flat roof structure and the arch structure. Figure 2.2 shows the arch structure proposed by Smithmeyer. The Secretary of the Interior modified the contract and an arch structure was constructed. Recent surveys by the Vicksburg District of the U.S. Army Corps of Engineers indicate interior dimensions similar to those shown on Figure 2.2 for the main tunnel. It is reasonable to assume that the wall and arch thicknesses shown on the Figure are correct.

2.3 Current Perspective

The 1993 problems are not that different than the 1883 problems the arch creek tunnel does not have the hydraulic capacity to contain the drainage from large storms and as a result water flows in the street. Various proposals have been offered. The Corps of Engineers is currently proposing a new tunnel through west mountain. Figure 2.3 which is taken from Corps of Engineers drawings, shows a map of the area and a plan view of the drainage facilities. The main tunnel is approximately between Stations 183+00 and 230+00. The Whittington Avenue tunnel is to the left and the Park Avenue tunnel is to the right.

All proposals to control flooding must consider first the single factor of paramount importance, that is protection of the natural resource of the hot springs. The unique and unusual geologic conditions practically preclude blasting excavation methods in the existing tunnel.

Since potential excavation methods are limited to hand mining; enlargement of the Hot Springs Tunnel System does not appear to be an economically feasible option to increase the capacity of drainage facilities. Given that supposition, this report is confined to evaluation of the existing structure and does not consider drainage improvements.

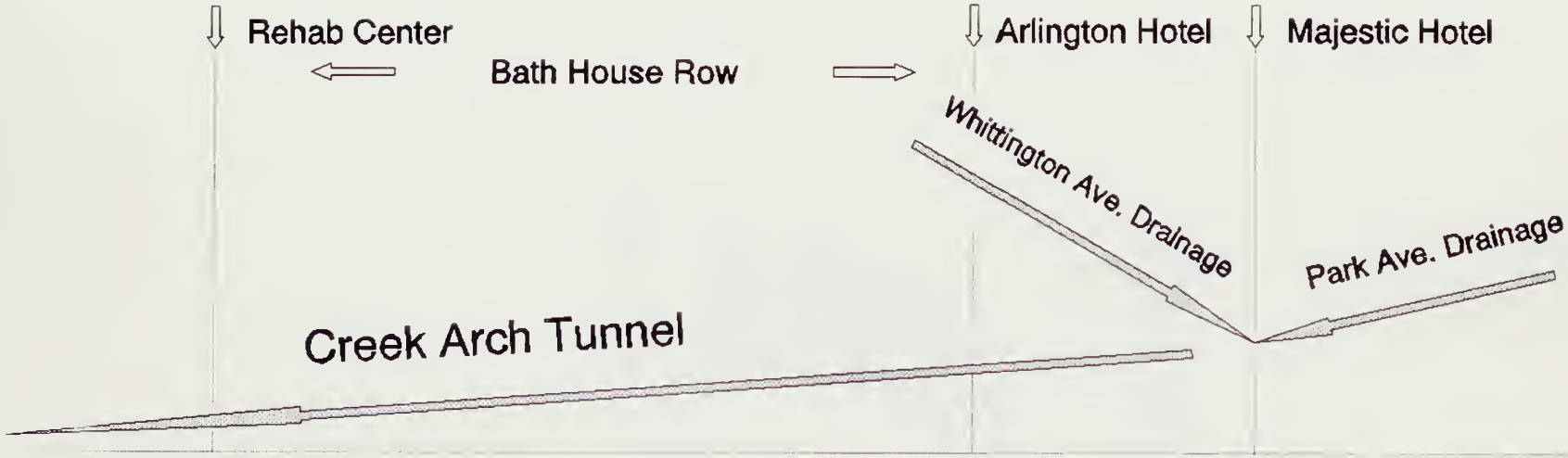
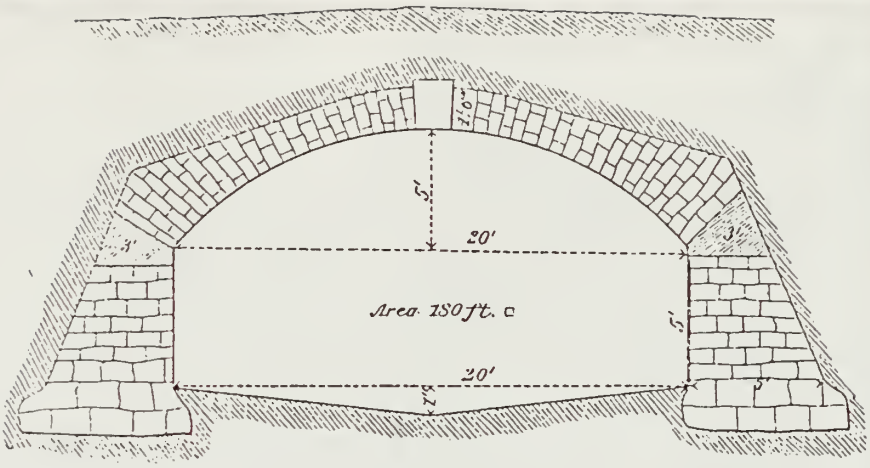
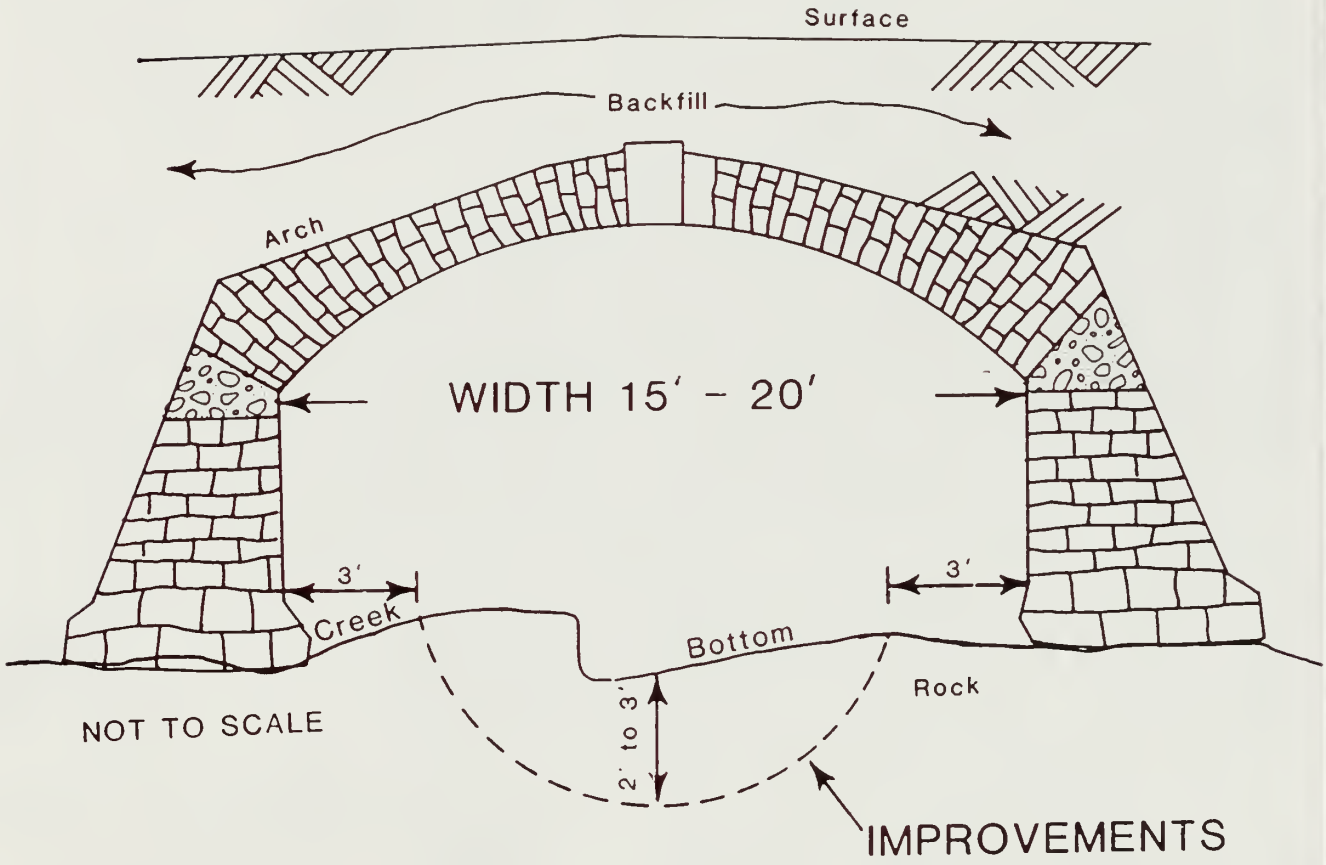


Figure 2.1 Hot Springs National Park and the City of Hot Springs, Arkansas Storm Drainage System





OUACHITA RIVER BASIN
HOT SPRINGS, ARKANSAS
FLOOD CONTROL RECONNAISSANCE STUDY
HOT SPRINGS CREEK
ARCH CROSS SECTION
WITH PROPOSED EXCAVATION
U.S. ARMY ENGINEER DISTRICT, VICKSBURG
CORPS OF ENGINEERS
VICKSBURG, MISSISSIPPI
DATE: FEB 1990

Figure 2.2 **Cross Section of Creek Arch Tunnel.** Inset shows original drawing by Smithmeyer (from Congressional Record provided by Vicksburg COE)

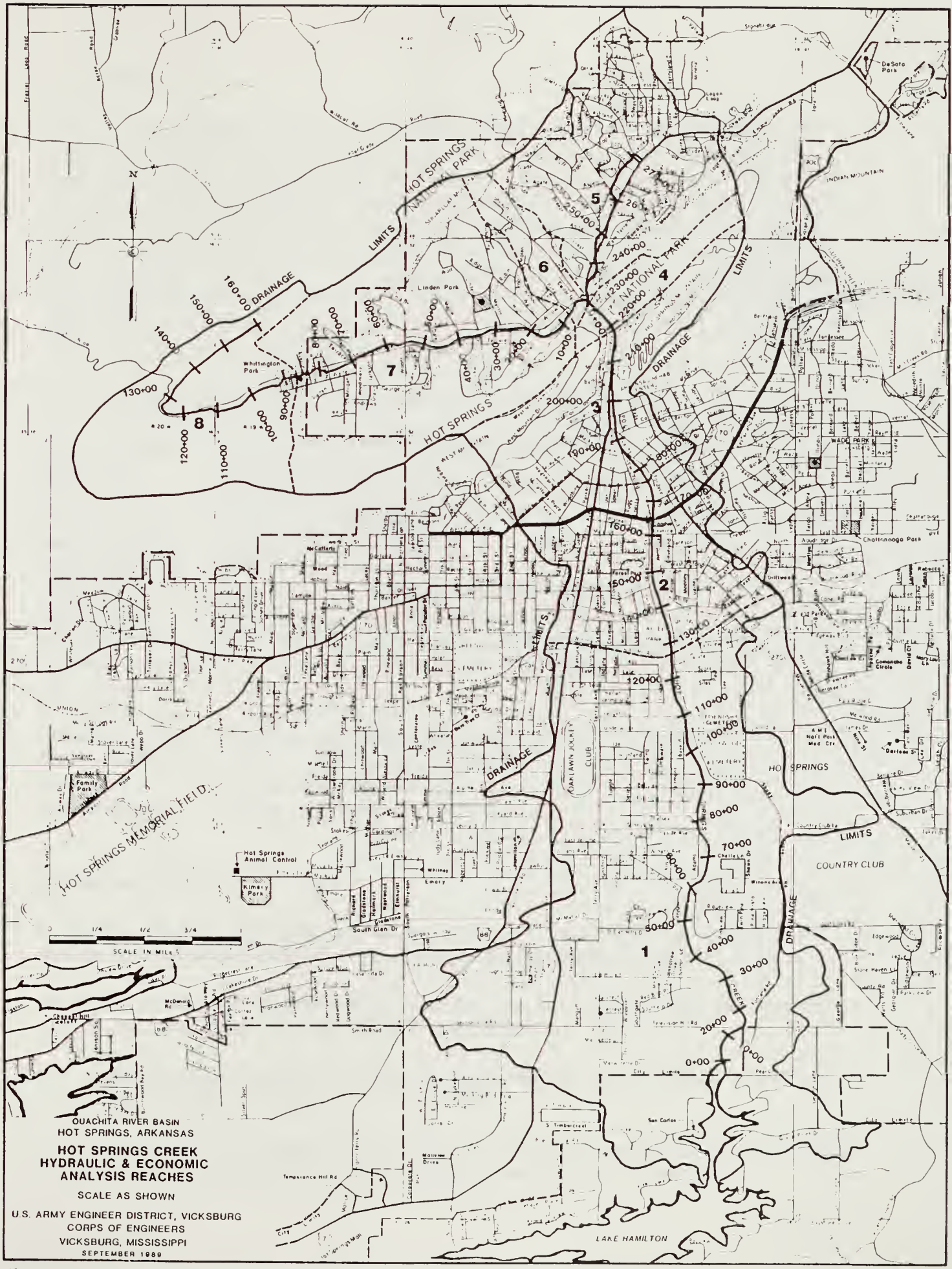


Figure 2.3 Corps of Engineers Drainage Map of Hot Springs

3.0 Inspection

The morning of August 3, 1993 the individuals listed below gathered for a briefing on the current performance of the Arch Creek Tunnel. Mr. Jim Atchley and Mr. Roger Giddings described the location of the tunnel and the problem of flooding in the National Park and the City of Hot Springs. At the conclusion of this briefing part of the group prepared to inspect the tunnel. The purpose of the tunnel inspection was to observe the structural condition of the tunnel. Operation and maintenance procedures and the impact of the tunnels of public safety were noted. Another part of the group undertook an evaluation of the National Park Service Flood Preparedness Plan and Recommendations for the integration of an automated early warning system into the Park operating plan. The early warning system would serve to reduce the risk of loss of life associated with flooding.

Meeting Attendees (names shown in bold inspected the tunnel)

Roger Giddings	**Superintendent, Hot Springs National Park**
Dale Moss	Hot Springs National Park
Len Lawson	Hot Springs National Park
Ron Jordan	Hot Springs National Park
James Meredith	**Hot Springs National Park**
Earl Adams	**Hot Springs National Park**
Eric Woerner	**U.S. Army Corps of Engineers, Vicksburg**
Ed Chisolm	**U.S. Army Corps of Engineers, Vicksburg**
Bob Fitzgerald	U.S. Army Corps of Engineers, Vicksburg
Pat Hall-Hemphill	U.S. Army Corps of Engineers, Vicksburg
Jim Atchley	City of Hot Springs
Dave Stanage	**City of Hot Springs**
Charles G. Stone	**Arkansas State Geological Survey**
Pat Hagan-Chagnon	Bureau of Reclamation, Denver
Bob Swain	Bureau of Reclamation, Denver
John Steighner	**Bureau of Reclamation, Denver**

3.1 Previous Inspections

A repair specification was issued in 1964 and repair work was successfully completed. In that specification undermining of the foundation of the tunnel was a major item of work.

Mr. Luther Newton and Mr. Scott Vowinkel of the Corps of Engineers inspected the tunnel in February 1984. They noted the following deficiencies:

Undermining of wall bases. These inspectors noted greater undermining of the arch walls in reaches upstream of the National Park.

Pipes Entering the Tunnel. The potential for erosion of backfill around the arch due to migration of material into or around the pipe was cited by the inspectors.

Missing Mortar: Replacement of missing mortar was recommended.

These inspectors described the overall condition of the arch as good. A regular inspection and maintenance program was recommended.

Another inspection was made by Earl Adams of the Hot Springs National Park on May 4, 1993. Mr Adams concentrated on an evaluation of the water balances in the tunnel and bath houses. He did note undercutting of the tunnel sidewalls.

The Corps of Engineers surveyed the tunnel in 1989 and 1993. That survey information will provide excellent data to describe the tunnel condition in drawing form.

3.2 Inspection Summary and Photographs

The morning of August 3, those inspecting the tunnel entered the Arch Creek Tunnel at the outlet (about Station 183+00 on Figure 2.3). Photo 3.1 shows the headwall of the outlet.

In the outlet reach the Arch sidewalls are founded on a shale rock unit. Significant undermining of the sidewalls was noted in this reach. Photos 3.2 and 3.3 show erosion at the base of the sidewalls and in the invert of the tunnel.

In general the arch appeared to be in good condition loose rock blocks were observed in the sidewalls where the foundation had been undermined, however; the arch and sidewalls usually appeared to be well cemented without loose blocks. Photo 3.4 shows the arch and sidewall of the tunnel. The painted number on the sidewall may be related to a recent Corps of Engineers survey in the tunnel.

Throughout the tunnel openings in the arch and sidewalls are evident. Photo 3.5 shows a pipe entering the tunnel with water flowing down the sidewall of the tunnel. Photo 3.6 shows a wooden blockout in the crown of the tunnel.

We exited the tunnel via a ladder access at the Fordyce Bathhouse Visitor's Center.

After lunch we entered the Whittington Avenue section of the tunnel. Photo 3.7 shows the tunnel entrance on the Whittington leg. A corrugated metal section extends a short distance into the tunnel.

In some reaches the arch has been covered with shotcrete. Photo 3.8 shows a section of the tunnel with a sound shotcrete coating.

In the reaches of the tunnel near Hot Springs Mountain hot water collection and distribution pipes are supported on the sidewalls and occasionally cross the tunnel. Photo 3.9 shows a pipe across the arch.

The shotcrete coating on the arch has eroded in many places through the tunnel. Photo 3.10 shows the deterioration of the shotcrete coating.

Photos 3.11 and 3.12 were taken from the surface after we exited the tunnel. The area is one of immediate concern. After we observed a somewhat haphazard arrangement of structural steel beams and pipe bracing in the tunnel, we inspected the surface to find the remains of an old structure with unprotected openings to the tunnel. The concrete structure was a thin slab supported by the steel beams we observed in the tunnel. It appeared that vehicles could park on the slab. We discussed the apparent danger with the city representative Dave Stanage on the spot. Structural modifications to this area are needed.

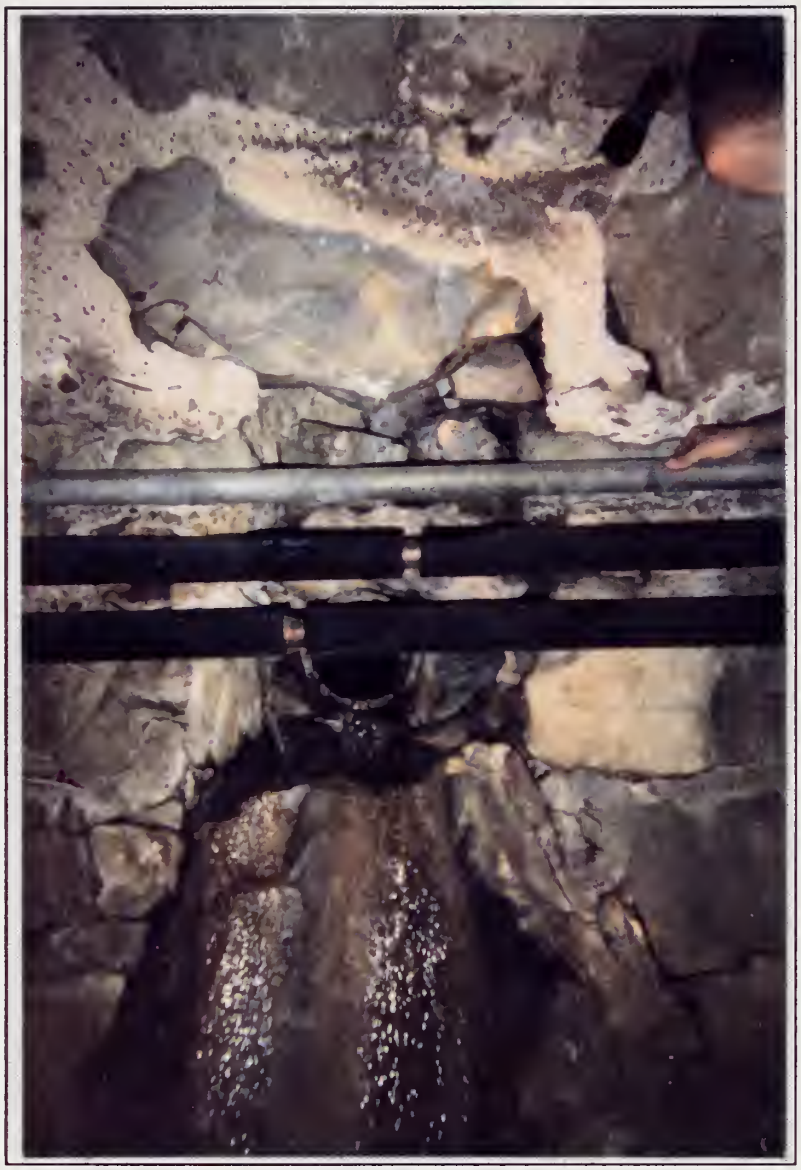
Photo 3.13 again shows erosion at the base of the sidewall of the tunnel. This photo was taken in a section upstream of the Fordyce Bathhouse Visitor's Center. Again the masonry of the sidewalls appears to be in good condition.

3.1 Inspection party entering the outlet of Arch Creek Tunnel.
(About Station 183+00 COE Drainage Map Figure 2.3)

3.2 Sidewall of the Tunnel. The base of the sidewall has been severly undercut. The concrete traces the base of a previous repair. (About Sta. 187+00.)

3.3 Pedestal and Erosion of the Tunnel Invert (About Sta. 190+00)

3.4 Arch and Sidewall. (About Sta. 200+00)



3.5 Drainage Entering the Tunnel.
(About Sta. 205+00)

3.6 Crown of the Tunnel. Wooden blockout for drainage into the tunnel is visible in the crown. (About Sta. 200+00)

3.7 Whittington Avenue Entrance. The structural steel plate is just visible inside the tunnel. (About Sta. 72+00 Whittington Ave Branch COE Map Figure 2.3)

3.8 Tunnel Crown. Shotcrete or gunite treatment. (About Sta. 60+00 Whittington Branch)

3.9 Insulated Piping Crossing the Tunnel Crown.

3.10 Deterioration of the Shotcrete in the Crown of the Tunnel. (About Sta. 235+00)

3.11 Vault near Arbor and Loadstone Streets. (About Sta. 238+00)

3.12 Vault near Arbor and Loadstone. Unprotected opening and slab thickness are shown.

3.13 Erosion of the Base of the Sidewalls of the Tunnel.
Erosion of previously placed concrete is visible.
(About Sta. 240+00)

4.0 Operation, Maintenance and Public Safety

Mr. Charles Karpowicz of the Washington D.C. office of the National Park Service requested a detailed occupational and public safety inspection. This report does not satisfy the need for that detailed inspection. The following paragraphs contain some observations on the public safety impact of the tunnel system.

The Hot Springs Tunnel System does present a public safety risk. Loss of life is possible; someone swept into the tunnel during high flows would probably not survive. The risk may be similar (in nature, not in a statistical sense) to the risk presented to a child playing near a heavily trafficked thoroughfare. Some possible actions intended to improve public safety are listed below. This inspection was not aimed at an evaluation of public safety so the comments below may be taken as material for further discussion. An evaluation of the potential increased flooding and the public safety risk is one of the recommendations of this report.

4.1 Warning Signs and Guardrail

Signs to warn the public of the danger of rising water and to advise individuals of a proper course of action appear to be a very reasonable safety measure. Likewise, guardrail near the tunnel entrances appears to be a reasonable safety measure.

4.2 Safety Racks

The idea of protecting the tunnel entrances with safety racks to prevent people from entering the tunnel appears to be a good idea. Two considerations may complicate a decision on safety racks. First, the racks will provide a good access ladder to the creek bottom and may become an attractive nuisance. Second, these protective structures will exclude trash from the tunnel, however; the trash will accumulate on the racks. Provision to clean the racks during most storms is an essential part of the safety rack installation. Failure to remove trash even during the frequent storms could aggravate the flooding problem. Safety racks certainly deserve serious consideration. The evaluation of risks is probably best considered by people most familiar with the locality and within the scope of the entire drainage problem. Some structural alternatives may eliminate the safety risks of the Creek Arch. Without a more through consideration of the non structural factors listed above it appears to be premature to unequivocally recommend immediate installation of safety racks.

4.3 Tunnel Hydraulic Capacity

Protection of the Hot Springs effectively precludes and enlargement of the existing tunnel by blasting or any method which may alter the hydrologic regime of the hot springs area. Some hydraulic improvement may be possible by paving the invert of the tunnel. The Corps of Engineers estimated a Manning's roughness coefficient for existing conditions of 0.05. The Corps also suggested a reduction in roughness to a Manning's n of 0.015 was possible. This potential improved hydraulic capacity could be part of a plan to make improvements for

floods less than the standard project flood.

4.4 Operation and Maintenance

Section 3 describes relatively infrequent inspections of the tunnel system. For an individual inspecting the tunnel for the first time, the lack of system drawings and the lack of a good record of problems and repairs complicates the observation process. If the National Park Service in cooperation with the City of Hot Springs pursues the recommended repair of the tunnel.

5.0 Conclusions and Recommendations

A serious safety problem is evident at the vault near Loadstone and Arbor Streets. The area should be fenced to prevent access and structural repair work should proceed.

Erosion of the base of the sidewalls of the Hot Springs Tunnel System is a serious structural problem. The masonry arch of the Hot Springs Tunnel System is in good condition. However, continued erosion of the foundation of the sidewalls of the tunnel could eventually result in collapse of a section of the tunnel. It is recognized that this problem requires an investment in planning and financing which cannot reasonably be executed in a matter of months. The urgency is to begin the repair process. We recommend the following steps:

Prepare drawings of the existing conditions. The existing openings and utilities and a description of the various sections should be shown. The survey data from the Corps of Engineers should be used. Mr Adams knowledge of the water transfers around bath house row should be preserved on these drawings.

Make a detailed structural survey. Permanent station markers should be set in the tunnel for all future surveys and engineering work. The condition of the foundation of the sidewalls should be described for the full length of the tunnel. The worst areas should be targeted for repair.

Prepare a repair specification. Specifications and drawings should be prepared to describe the repair methods and to repair the most deficient areas.

Issue a repair contract. It appears a firm fixed price contract would be appropriate but given the hostile environment (for construction work), it may be effective to solicit proposals and negotiate a repair contract.

It may be possible to accomplish a great deal of the work listed above using currently available funds leaving only the preparation of a repair specification and the actual construction contract as fiscal hurdles. It is important and urgent to begin the steps to maintain the integrity of the tunnel.

5.1 Numbered Recommendations

The first recommendation concerns the unsafe condition of the vault structure. Action is required immediately (analogous to safety of dams category SOD1).

1993-T1-1. Fence the vault area near the intersection of Loadstone and Arbor streets and cover openings to the tunnel.

The recommendations below affect the safety of the tunnel and the surface area subject to flooding. Action is required within 24 months (analogous to safety of dams category SOD2).

1993-T2-2 Complete an engineering inspection of the entire tunnel system. Prepare drawings showing all pipe connections and piping systems in the tunnel. Show all exhibiting structural anomalies. Prepare a specification for repair of the undercutting of the sidewalls of the tunnel.

1993-T2-3 Analyze the need for safety racks at the entrances to the tunnels. Establish the consequences of flooding due to trash blockage of the tunnel entrances.

1993-T2-4 Install guardrail, handrail and warning signs as directed by the Hot Springs National Park safety officer.

5.2 Revised Inventory Report

A marked copy of the official National Park Service Engineering and Safety Services Division Dams and Related Floodplain Inventory Report is included on the next page of this report.

NATIONAL PARK SERVICE
ENGINEERING AND SAFETY SERVICES DIVISON
DAMS AND RELATED FLOODPLAIN INVENTORY REPORT

Refer to NPS DAMS INVENTORY USER GUIDE, revised December 1992, for explanation of data elements.
Refer to NPS Special Directive 87-4 and NPS-40 Guideline for help or call 202-343-7040.

1) NPS Number: 372
2) Dam ID: AR
3) Region: Southwest Regional Office
4) Park : HOT SPRINGS NATIONAL PARK
5) NPS Organization Number Code: 7300
6) Name: NPS PORTION OF HOT SPRINGS CK.TUNNEL
7) Is this information about a dam? N-No
8) Latitude (i.e. 37-17.1) : - 0.0
9) Longitude (i.e. 076-38.5) : - 0.0
10) Owner: DOI NPS
11) Ownership : G-Federal but not Corps
12) Is project located within park boundaries: Y-Yes
13) Federally regulated: Y-Yes
14) Purpose: C-Flood Control
Z-Historic Structure

NPS Emergency Action Plan (EAP) Information per NPS-40

31) Date of Triennial Test of EAP: 05/20/90
32) Date of Annual Verification of NPS prepared EAP: 03/01/91
33) Position Title of NPS EAP Coordinator: Chief Ranger
34) NPS 24-HR EAP Emergency Phone: 501-624-3124
35) Position Title of Local Non-NPS EAP Coordinator: Hot Springs Police
36) Local non-NPS 24-Hr EAP Emergency Phone: 501-623-6787

15) Type of construction: ER-Rockfill

16) Structural height in feet: 17
17) Maximum capacity in acre-feet:
18) Size class: 2-Small

NPS Funding Information

37) Accumulative funds used or obligated FY 80 - FY 93: 40266
38) Accumulative funds programmed from FY 94 - FY 97: 0
39) Is facility funded for periodic maintenance and repair? Y-Yes

Inspection Results and Corrective Action Information

19) Hazard Potential Classification: 1-High
20) Organization(s) who prepared report: HOSP CELMK
21) NPS Inspector or Observer: Giddings, Rogers
22) NPS Inspector/Observer Date of Training:
23) Date of last inspection report completed: 02/23/84
24) Type of report: 4-Other
25) Is maintenance log being kept per NPS-40? N-No

BR

New Data Elements - Please Complete

15.1) Year originally constructed: 1883
15.2) Year last reconstructed: 1964
25.1) Is project in NPS Maintenance Management System? unknown

1084

Condition Classification

26) Has project ever failed or misoperated? Y-Yes
27) U.S. Bureau of Reclamation Safety:
28) NPS Operations/Maintenance: 3-May not fullfill intended purpose and maintenance or major repair is needed.
29) All Outstanding Deficiencies: SC-Spillway Capacity
SR-Structural
OP-Operations or maintenance
OT-Other
30) Corrective Action Codes: ON-Other Non-emergency actions

40) Remarks: 29-SC: HOSP & City should install debris removal system @ tunnel entrance & remove all flow restrictions in tunnel and downstream channel. 23 & 24-: Reference NPS-WASO 06/08/1983 Report and Corps 02/23/84 Report. 26 & 28-3: Project failed to provided adequate protection. 30-ON: Some improvements being made.

HOSP & City should contract for a detailed facility survey and structural repair specification

Name of Verifier: Title: Telephone: Date:

H